THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

AN INVESTIGATION OF DIAPHRAGM CHARACTERISTICS

PART I: COMPARISON OF DIAPHRAGM TYPES 305A AND 305B IN A SIMULATED "LIFE" TEST AND AN EXPLORATORY INVESTIGATION OF DIAPHRAGM CONTRIBUTION

Project 1108-26s

Preliminary Report One

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

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TABLE OF CONTENTS

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ABSTRACT

Recently The Institute of Paper Chemistry advised the Fourdrinier Kraft Board Institute that bursting strength results in the liner baseline study would be based on the new type diaphragms currently supplied by the manufacturer as its supply of the older type diaphragms was exhausted. Both a change in diaphragm design as well as composition was involved. The new design (type 305B) differs from the older design (type 305A) in that the thickness is gradually tapered from the inner edge of the rim to the center of the diaphragm.

Because of the importance of the bursting strength tester to the linerboard industry, a subcommittee was set up to enlist the co-operation of B. F. Perkins & Son, Inc. in diaphragm and tester standardization. As a result of the various meetings, it was decided to pursue a research program for the general purpose of (a) identifying diaphragm characteristics which govern diaphragm life and contribution and (b) to develop specifications for diaphragms.

As a first step, it was decided to comparatively evaluate diaphragm types 305A and 305B with regard to their bursting strength results, life and diaphragm contribution. Both diaphragm types were to be molded from Sirvene 409641 (material used in 1950). For comparison purposes, two additional diaphragm types were also evaluated as follows:

(a) Current commercial design (apparently type 305B but differing in composition from the 1950 standard).

(b) Natural rubber--apparently type 305A (an old style diaphragm believed to be molded from natural rubber and obtained from the Institute stock).

Diaphragm evaluation was carried out in two ways--namely,

1. A simulated life test carried out to 1050 tests using 42-lb. kraft liner.

2. Comparison of diaphragms on the basis of apparent diaphragm contribution.

For the latter phase an approximate method based on pressure vs. distention curves for diaphragm alone and in the normal test was selected for study. This present report describes the design of the equipment for obtaining the pressure vs. distention curves and presents the preliminary results obtained.

The following results were obtained in the simulated life test using 42-lb. kraft liner as the test material.

1. Within each type of diaphragm, the bursting strength results were reasonably uniform.

2. No consistent trend for the bursting strength results to decline with number of extensions was evident for any of the diaphragm types.

3. Diaphragm pressure at 1.8 cm. (0.71 inches) decreased markedly with number of extensions; however, at 3/8 inch extention, the diaphragm pressure was nearly constant with number of extensions.

4. Items 2 and 3 taken together may be indicative that diaphragm pressure at 3/8 inch is a better measure of diaphragm condition than pressure at 1.8 cm. when 42-lb. liner is tested.

5. In terms of over-all averages, the differences between diaphragm types were relatively small--implying that the differences in diaphragm pressure encountered herein were not sufficient to cause marked differences in test results.

6. In terms of Rule 41, the type 305A Sirvene 409641 diaphragms were below specifications, on the average, while the natural rubber diaphragms (type 305A) were above specifications.

With regard to diaphragm contribution, the approach followed herein consisted of obtaining pressure vs. distention (p-d) curves during sample tests. The extension at failure was read from the curves and the diaphragm pressure at the failure extension was then obtained from a p-d curve for the diaphragm alone. The apparatus was designed to use circular film type potentiometers to measure pressure and distention (through a lever arrangement), and the output of the potentiometer was recorded on an oscilloscope.

The exploratory results reported herein appeared to indicate the following:

1. For one sample of kraft liner, the distention at failure was about 0.14 inches.

2. As a result of the low distention at failure using kraft liner, the apparent diaphragm contribution for the conventional diaphragms was near 8 p.s.i.g. or about 5 to 7% of the bursting strength for the sample used.

3. The diaphragm contributions for the two conventional diaphragm types investigated were nearly equal. This would imply that the bursting strength results for the two diaphragm types would also be approximately equal--in qualitative agreement, at least, with the "life" data.

INTRODUCTION

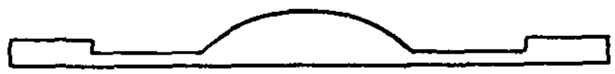
During the early years of the Fourdrinier Kraft Board Institute program, The Institute of Paper Chemistry conducted an extensive study of the bursting strength test and much current knowledge of the instrumental variables dates to that period. However, references in the literature with regard to the effect of diaphragm characteristics date back to a considerably earlier time. For example, Abrams, in 1925, commented that when a new diaphragm is substituted for one which has been in use long enough to lose its elasticity, an increase up to 14% may be expected in the test (1). Other early references to the effect or lack of effect of the diaphragm characteristics may be found in references (2) through (5).

In reference (6), the Institute reported to the Fourdrinier Kraft Board Institute that the diaphragm characteristics could materially affect bursting strength results and suggested the procedure of selecting or rejecting diaphragms on the basis of diaphragm pressure at a fixed extention. Present Institute specifications that the diaphragm pressure fall between 40 and 45 p.s.i.g. at 1.8 cm. distention stem from that work. Rule 41 requirements that diaphragm pressure fall between 23 and 30 p.s.i. at 3/8 inch distention are similar in philosophy. Additional information on the effect of diaphragm pressure on bursting strength results obtained with the Cady and Model C testers was presented in references (7) and (8).

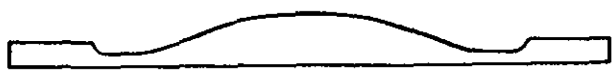
In 1957, the manufacturer introduced a new diaphragm design (type 305B) differing from the older design (type 305A) in that the thickness was gradually tapered from the center of the inner edge of the rim. A schematic diagram of the two designs is shown in Fig. 1. A number of changes in the composition of the molding material have also been made in the last decade or more as well as changes in design--lower platen, clamping, etc.

Recently the Institute advised the Fourdrinier Kraft Board Institute that its supply of the older type diaphragms was exhausted and that the new type diaphragms would be used in the liner baseline study beginning with March of this year (9). (Note: Both a change in diaphragm design and composition were involved.) It may be remarked that it had been Institute practice to purchase diaphragms in large quantities in an effort to avoid variations due to manufacturing changes. While somewhat contradictory results were obtained in a comparison of the old and new type diaphragms, it appeared that the new type diaphragms exhibited shorter life and might cause an increase in the industry bursting strength level of as much as 2 or 3 p.s.i.g. (9).

Because of the importance of the bursting strength tester to the linerboard industry, a subcommittee of Fourdrinier Kraft Board Institute met with representatives of B. F. Perkins & Sons, Inc. for the purpose of enlisting their co-operation in diaphragm and tester standardization. This meeting was held in April of this year and the agreement was reached that it would be desirable if the Institute could evaluate changes in tester design or diaphragms prior to their commercial use. A co-operator investigation of factors important to diaphragm standardization was decided upon as the first step. As a result, a meeting was held with representatives of the Chicago Rawhide Manufacturing Co. (manufacturers of the diaphragms for B. F. Perkins & Sons, Inc.) in May. At that meeting, it was decided to comparatively evaluate diaphragm types 305A and 305B with regard to their bursting strength performance.



Type 305 A



Type 305 B

Figure 1. Schematic Drawing of Old (Type 305A) and New (Type 305B) Bursting Strength Diaphragms

For that purpose, Chicago Rawhide Manufacturing Company was to supply 20 diaphragms of each type to the Institute for evaluation. The diaphragms were to be molded on a single-cavity die (to possibly achieve better uniformity) from molding compound Sirvene 409641 (material used in 1950). The present report discusses the initial results obtained in evaluating the two diaphragm types.

In general terms, the problem may be outlined as follows:

I. Development of method for determining the life of a diaphragm.

II. Development of method for determination of the diaphragm contribution to bursting strength.

III. Development of diaphragm specifications to maintain the diaphragm contribution within permissible tolerances.

   a. Identification of diaphragm characteristics which govern life and contribution.

   b. Determination of desired levels of life and diaphragm contribution.

   c. Development of methods for diaphragm specification.

In terms of the above goals, this report is divided into two sections--namely

1. Comparative evaluation of diaphragm in a simulated life test.

2. Diaphragm contribution as determined from pressure vs. distention characteristics of diaphragms and the distention at break in the bursting strength test.

MATERIALS

DIAPHRAGMS

Chicago Rawhide Manufacturing Company supplied 20 diaphragms of the following types:

1. Type 305A, Sirvene 409641--old style with clearly defined center portion. The Sirvene 409641 composition was used in early 1950's.

2. Type 305B, Sirvene 409641--new style with gradual taper from center.

The type 305A diaphragms were manufactured in a single cavity mold while the type 305B diaphragms came from Perkins standard mold. To characterize the diaphragms in terms of thickness, each diaphragm was evaluated for thickness at center and rim using a standard Cady Micrometer caliper and at center, rim and thin section using a special modified caliper (3/8 inch anvil and 100 gram force). Durometer hardness measurements were taken at center and rim on each diaphragm supplied. These measurements are summarized in Tables I and II where it may be noted that the diaphragms were reasonably uniform in both caliper and hardness.

In addition to the above, "life" tests were also performed using two additional lots of diaphragms as follows:

1. Current commercial diaphragms.--These are type 305B diaphragms but differ in composition from the diaphragms mentioned above.

2. "Natural rubber" diaphragms.--These were obtained from an old stock at the Institute and are believed to have been molded using natural rubber. They were of the type 305A style.

TEST LINER

For the life study, one sample of 42-lb. kraft liner was obtained and divided into two portions--one of which was carefully randomized, preconditioned and conditioned. The other portion was used for the "waste" tests in the life evaluation.

TABLE I

CALIPER AND DUROMETER TESTS ON OLD STYLE 305A DIAPHRAGMS MOLDED FROM SIRVENE 409641

Diaphragm No.	Caliper, inches x 10^{-3} (Modified Caliper--100 g. Pressure), Center	Rim	Thin Section	Caliper, inches x 10^{-3} (Standard Caliper--8 p.s.i. Pressure), Center	Rim	Durometer Hardness, Center	Rim
	n=1	n=4	n=4	n=1	n=4	n=1	n=4
1	103.0	68.4(1.1)	39.3(0.6)	102.0	68.4(1.0)	60	63
2	104.9	69.6(2.7)	40.6(1.6)	103.0	69.4(2.5)	60	61
3	104.4	69.6(2.6)	40.6(1.6)	101.2	69.6(2.8)	59	60
4	104.0	69.3(2.2)	40.0(1.2)	101.1	69.1(1.5)	58	60
5	104.5	70.0(3.3)	41.0(1.2)	102.0	70.0(3.7)	61	62
6	103.6	68.7(1.7)	39.5(1.1)	101.1	68.6(1.5)	60	60
7	103.6	68.9(2.0)	39.8(1.6)	101.2	68.9(1.9)	60	63
8	104.5	69.5(1.9)	40.4(1.4)	102.0	69.5(2.5)	59	62
9	103.2	68.6(1.4)	39.4(0.9)	101.0	68.5(1.1)	61	61
10	103.0	68.6(1.3)	39.3(0.6)	101.2	68.5(0.9)	58	60
11	104.8	70.2(2.7)	40.8(2.0)	102.0	70.1(2.6)	59	61
12	102.5	68.1(0.4)	38.8(0.5)	100.0	68.0(0.2)	60	62
13	104.1	69.5(2.4)	40.2(1.5)	101.9	69.4(2.5)	60	61
14	103.0	68.5(1.3)	39.3(1.4)	101.0	68.7(1.1)	60	62
15	103.2	68.4(0.9)	39.4(0.5)	101.9	68.4(0.9)	60	63
16	103.0	68.4(1.1)	39.4(0.9)	101.2	68.3(0.7)	59	61
17	103.6	69.0(1.8)	39.9(0.9)	101.2	69.0(1.8)	60	62
18	103.1	68.5(1.4)	39.6(0.9)	100.8	68.4(1.1)	60	61
19	102.8	68.4(1.0)	39.2(0.6)	100.5	68.4(0.9)	60	61
20	103.5	69.0(1.2)	39.6(1.1)	101.0	69.0(1.1)	60	62
Av.	103.6	69.0	39.8	101.4	68.9	60	61
Range	2.4	2.1	2.2	3.0	3.1	2	3

Note: Parentheses indicate range for the four measurements.

TABLE II

CALIPER AND DUROMETER TESTS ON NEW STYLE 305B DIAPHRAGMS MOLDED FROM SIRVENE 409641

Diaphragm No.	Caliper, inches x 10^{-3} (Modified Caliper--100 g. pressure) Center	Rim	Thin Section	Caliper, inches x 10^{-3} (Standard Caliper--3 p.s.i. Pressure) Center	Rim	Durometer Hardness Center	Rim
	n=1	n=4	n=4	n=1	n=4	n=1	n=4
EP6-1	99.2	62.1(2.8)	36.1(1.6)	96.9	62.0(3.3)	60	64
EP6-2	99.6	62.5(3.4)	36.3(1.8)	96.3	61.6(3.0)	61	64
EP7	98.7	62.5(0.7)	36.2(0.4)	96.1	62.0(1.3)	59	64
EP10	98.2	63.0(1.9)	36.9(0.6)	95.7	63.0(2.4)	61	64
EP11	98.6	62.1(4.8)	36.0(1.2)	96.0	61.6(5.0)	61	65
EP12-1	99.6	62.3(1.6)	36.0(0.9)	97.0	62.0(2.1)	62	66
EP12-2	98.9	61.8(1.8)	35.6(0.9)	96.1	61.8(2.6)	62	64
EP13-1	99.7	63.8(2.7)	37.1(2.4)	97.0	63.5(1.3)	61	64
EP13-2	99.6	63.9(1.9)	37.0(1.1)	97.0	63.0(1.8)	61	64
EP14-1	99.5	62.1(1.4)	36.2(1.4)	97.0	62.2(2.4)	62	65
EP14-2	99.0	61.8(3.0)	35.4(0.9)	96.1	61.4(3.3)	61	65
EP15	101.5	62.5(4.1)	36.4(1.8)	98.9	62.0(4.0)	61	65
EP16	99.1	61.2(2.0)	35.7(1.8)	96.9	60.7(1.9)	60	64
EP17	98.1	61.7(1.7)	35.7(1.3)	95.9	61.6(2.4)	60	65
EP18	99.6	63.1(0.8)	36.7(0.7)	97.0	62.9(0.3)	61	64
EP19	99.4	61.7(1.5)	35.2(1.0)	96.9	61.2(1.6)	61	64
EP22-1	101.1	64.2(2.3)	38.2(2.2)	98.9	64.0(2.9)	61	64
EP22-2	100.1	63.6(1.7)	36.8(1.4)	97.9	62.8(3.8)	61	64
EP23	98.6	63.6(1.2)	37.0(1.0)	96.1	63.2(2.0)	60	64
EP25	100.1	63.6(3.0)	36.8(1.9)	97.0	62.7(3.0)	60	64
Av.	99.4	62.7	36.4	96.9	62.3	61	64
Range	3.4	3.0	3.0	3.2	2.8	3	1

Note: Parentheses indicates range for the four measurements.

TEST PROCEDURE

COMPARATIVE EVALUATION OF DIAPHRAGMS IN A SIMULATED LIFE TEST

In this phase, the following procedure was employed:

1. Each diaphragm was installed in the tester and repeatedly distended (without test specimen) to 1.8 cm. until the distention pressures in four consecutive extensions were within ± 1 p.s.i. The distention pressure at both 3/8 inch and 1.8 cm. was recorded for each extension. (Note: These data have not been included in this report, however, with one exception, 8 to 10 distentions were sufficient to permit testing under the above criterion.)

2. After constant diaphragm pressures were obtained, the following tests were performed using the sample of 42-lb. kraft liner described previously.

a. Fifty tests were made--one on each of 50 sheets--with the wire side down. The diaphragm pressure at 3/8 inch and 1.8 cm. was checked after every 25 tests.

b. Two hundred waste tests were then performed with diaphragm pressure checks after every 25 tests.

c. Steps a and b were repeated until 800 waste tests (total 1050 tests) had been obtained.

3. Five diaphragms of each type were evaluated with the exception that only 3 diaphragms of the natural rubber type 305A were tested. The order in which the diaphragms were tested was randomized to minimize side

effects, and frequent checks on machine condition were made during the course of the testing.

DIAPHRAGM CONTRIBUTION AS DETERMINED FROM PRESSURE VS. DISTENTION CHARACTERISTICS OF DIAPHRAGMS AND THE DISTENTION AT BREAK IN THE BURSTING STRENGTH TEST

1. Description of apparatus

To obtain a graphic recording of the relationship between pressure and diaphragm extension, the following system was employed.

a. Pressure measurement: A circular motion film potentiometer was coupled to the needle of the pressure gage as shown in Fig. 2. The output of the potentiometer was fed into one axis of a d.c. oscilloscope.

b. Distention measurement: To measure diaphragm distention, a low mass lever was used to sense diaphragm displacement; the motion of the lever was then used to rotate a circular motion film potentiometer as shown in Fig. 3. The output of the potentiometer was then used to activate the other axis of the oscilloscope.

To illustrate the type of recordings obtained, Fig. 4 shows the pressure vs. distention curve for a diaphragm above (current commercial type) and during a test using 42-lb. kraft liner using the diaphragm.

2. Exploratory trials

Initial trials of the apparatus were carried out using three types of diaphragm, namely, (a) type 305A--Sirvene 409641, (b) current commercial type (type 305B), and (c) a dental dam. The first two were selected because of the differences in diaphragm pressure they exhibited in the diaphragm life

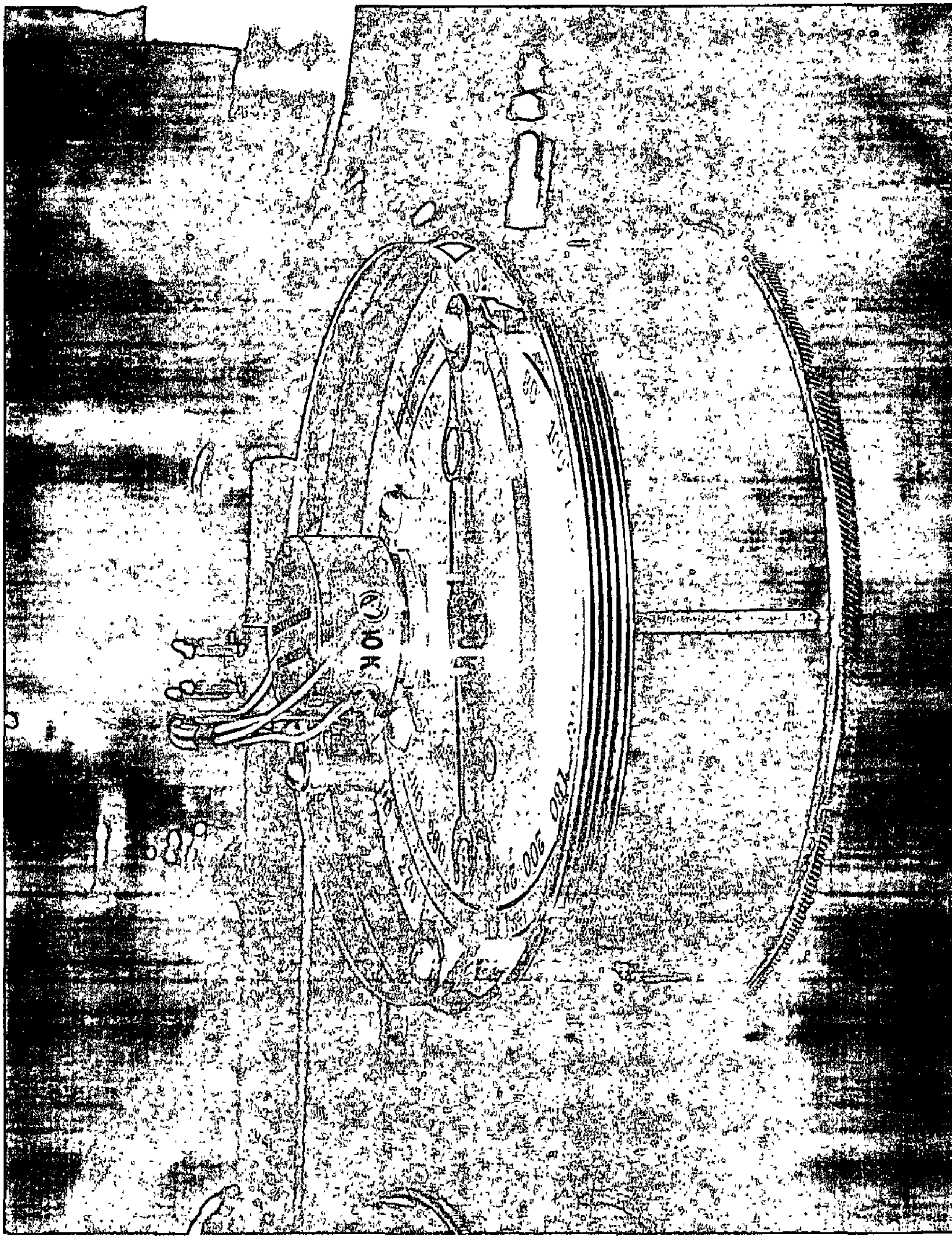


Figure 2. Film Potentiometer Attached to Pressure Gage

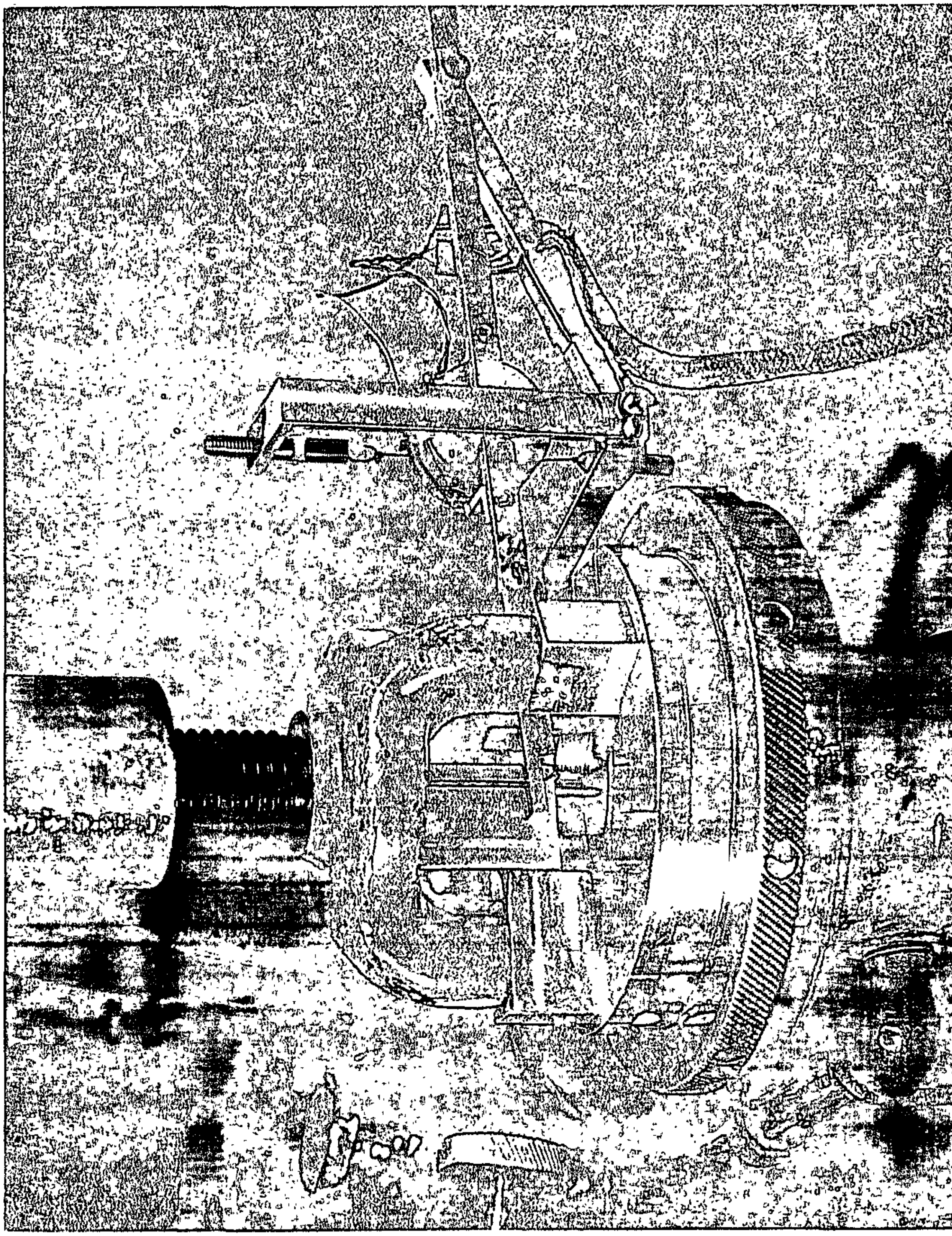
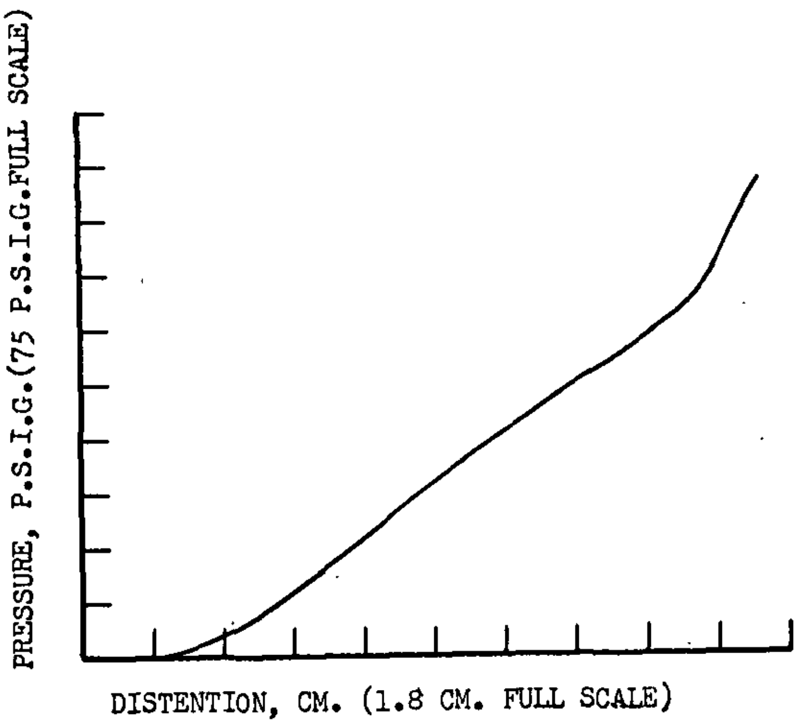
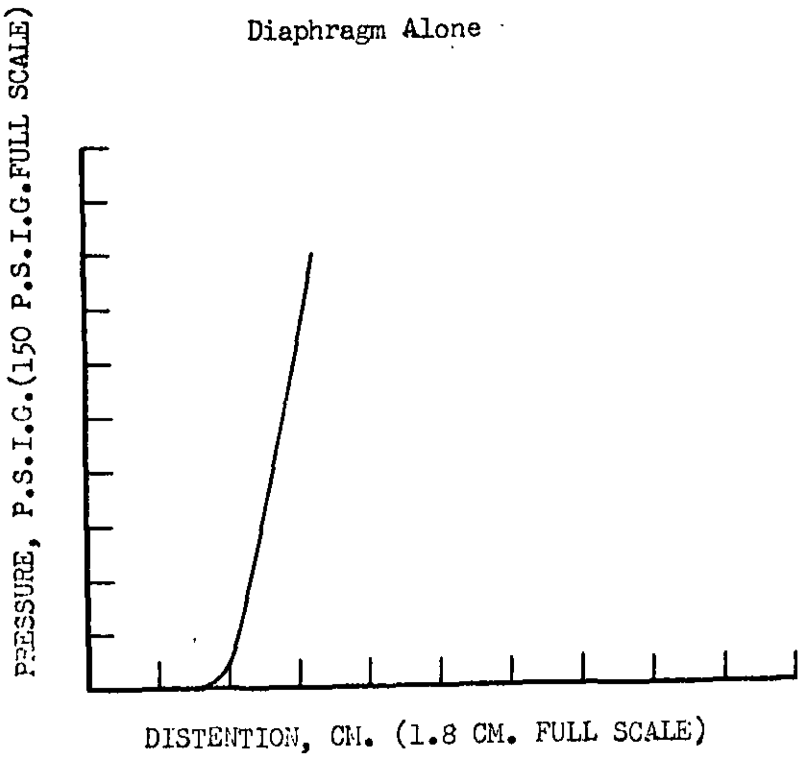


Figure 3. Distention Measuring Apparatus



Diaphragm Alone



42-lb. Kraft Liner

Figure 4. Pressure Distention Curves Obtained for Diaphragm Alone and During Test of 42-lb. Kraft Liner

tests, while dental dam was selected because it represents an extreme in pressure. The following procedure was employed:

a. Conventional diaphragms

(1) Install the diaphragm in tester and distend it 8 times noting the diaphragm pressure at 3/8 inch and 1.8 cm. on cycles 1, 6, 7, and 8.

(2) Obtain a pressure vs. distention curve for the diaphragm.

(3) Perform 30 tests using 42-lb. kraft liner, obtaining pressure vs. distention curves during tests 1, 5, 10, 15, 20, 25, and 30.

(4) Obtain a pressure vs. distention curve for the diaphragm.

(5) Perform 200 waste tests using 42-lb. kraft liner and repeat (2), (3), and (4).

(6) Repeat (1) through (4) using a new diaphragm and 0.003 inch annealed foil.

b. Dental dam

(1) Install the diaphragm and repeat Steps (1) through (4) above, using 42-lb. kraft liner.

DISCUSSION OF RESULTS

GENERAL

A bursting strength reading may be considered to equal the sum of two components--namely, (1) the diaphragm contribution at the moment of burst, and (2) the inherent test reading of the sample. For example, in Fig. 5, if the sample bursts at a distention A, the total pressure reading AC is the sum of component AB required to distend the diaphragm to A plus the component BC associated with the test specimen.

The above concept regarding the diaphragm contribution is simplified to the extent that it ignores the effect that the test specimen may have on diaphragm shape. The cited reference notes that during a test the diaphragm will be distended by the test specimen, increasing the tension in the diaphragm and, consequently, increasing the diaphragm contribution over what would be expected on the basis of free distention of the diaphragm (in the ordinary measurement of diaphragm pressure, for example).

With this reservation in mind, Fig. 5 indicates, among other things, that

1. The contribution of the diaphragm to the test reading depends on:
    a. The extension of the test specimen at failure.
    b. The diaphragm pressure at the failure extension.

2. For samples having equal extensions at failure, the percentage importance of the diaphragm contribution decreases as the bursting strength of the sample increases.

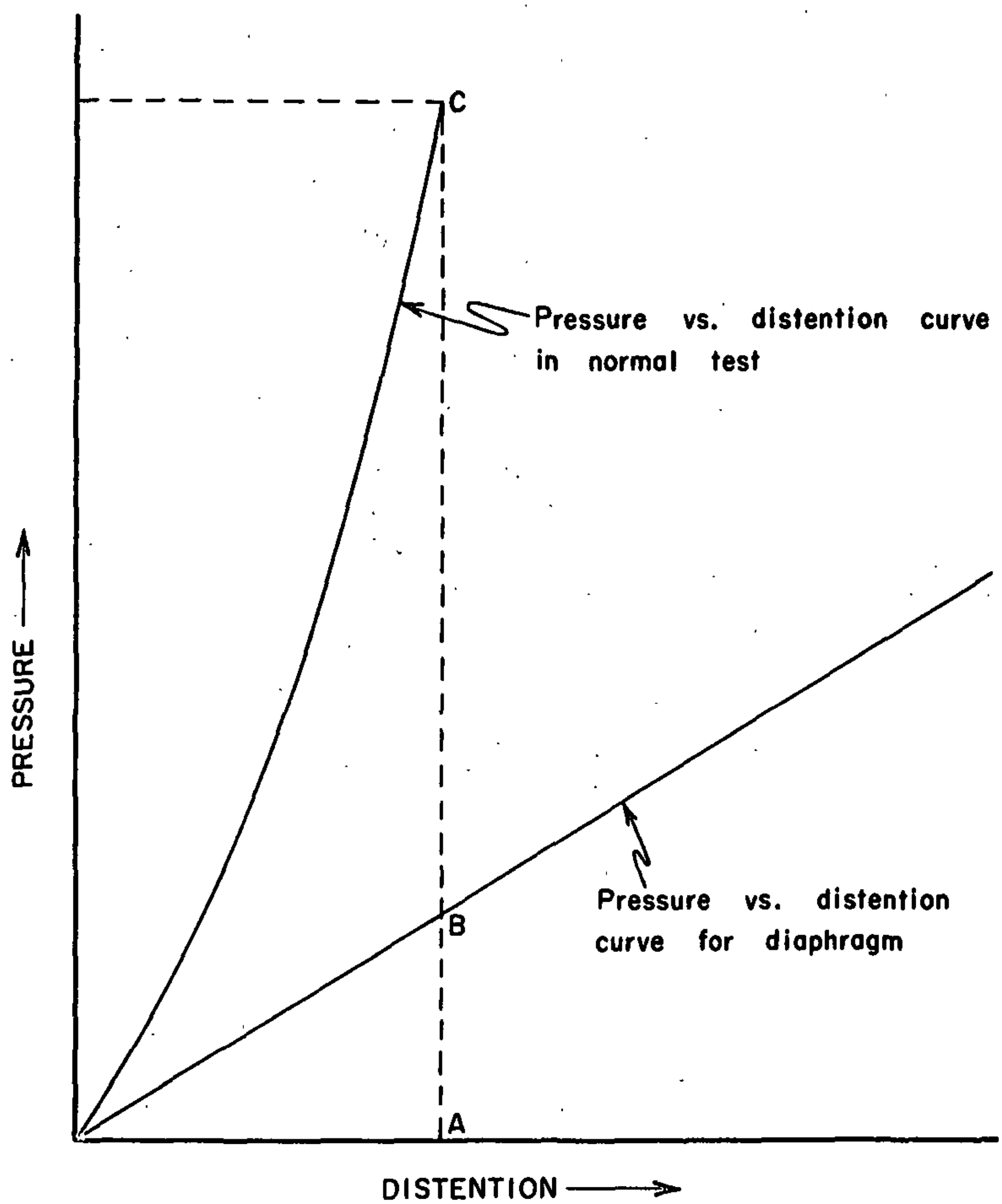


Figure 5. Schematic Illustration of Pressure *vs.* Distention Curves for Diaphragm and for Diaphragm plus Specimen

3. If the diaphragm contribution AB is small with respect to BC, then small variations in the diaphragm contribution may be obscured by the variability associated with BC or, conversely, relatively large differences in AB would be required to produce measurable changes in the bursting strength test value.

4. Significant changes in the diaphragm contribution must be avoided during the "life" of the diaphragm.

As mentioned previously, diaphragm suitability is, at present, defined by the condition that its pressure at a given extension must fall within stated limits. Therefore, diaphragm "life" is limited by either rupture of the diaphragm or by failure--after repeated testing--to meet pressure specifications. For this reason, initial work on this study was divided into two phases, namely, (a) diaphragm life and (b) diaphragm contribution.

COMPARATIVE EVALUATION OF DIAPHRAGMS IN A SIMULATED LIFE TEST

In the initial discussions on this project, it was felt that in the normal testing of linerboard, any diaphragm should be capable of giving satisfactory service for at least 1000 tests. As finally outlined, the procedure used herein was as follows:

For each diaphragm, 1050 tests were performed--after initially conditioning the diaphragm using 8 to 10 extensions to 1.8 cm. The tests were performed using a 42-lb. kraft linerboard sample. Test readings were recorded for Tests 1 through 50, 250 through 300, 500 through 550, 750 through 800, and

1000 through 1050. Measurements of diaphragm pressures were made after every 25 tests. (Note: Only the diaphragm pressure recorded for the intervals during which test values were noted are tabulated herein.)

Four types of diaphragms were evaluated:

a. Type 305A diaphragms molded from Sirvene 409641.

b. Type 305B diaphragms molded from Sirvene 409641.

c. Current commercial diaphragms--Type 305B.

d. Natural rubber composition--Type 305A.

The results obtained for each of the four types of diaphragms are summarized in Tables III through VI and the four types of diaphragms are compared in Table VII on the basis of composite averages. Referring to the tables, it may be noted that:

1. Within each type of diaphragm, the bursting strength results were reasonably uniform.

2. No consistent trend for the bursting strength results to decline with number of distentions was evident for any of the diaphragm types.

3. Diaphragm pressure at 1.8 cm. (0.71 inches) decreased markedly with number of distentions; however, at 3/8 inch distention, the diaphragm pressure was nearly constant with number of distentions.

4. Items 2 and 3 taken together may be indicative that diaphragm pressure at 3/8 inch distention is a better measure of diaphragm condition than pressure at 1.8 cm. for the 40-lb. liner sample used.

TABLE III

"LIFE" TESTS USING OLD STYLE DIAPHRAGMS ROLLED FROM SERVICE 409641

No. of Extension		Diaphragm 1 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 1 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 1 Bursting Strength, p.s.i.g.	Diaphragm 2 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 2 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 2 Bursting Strength, p.s.i.g.	Diaphragm 3 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 3 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 3 Bursting Strength, p.s.i.g.
0-50	Start	22	47		22	44		21	45	
	Middle	24	47	123.2	22	44	122.5	22	46	124.6
	End	24	46		22	44		22	47	
250-300	Start	23	38		21	35		21	39	
	Middle	23	37	126.5	22	35	123.6	22	39	123.1
	End	23	33		21	36		21	35	
500-550	Start	22	36		21	33		21	36	
	Middle	22	35	123.9	21	33	125.3	22	36	124.5
	End	22	35		21	32		21	36	
750-800	Start	21	35		21	32		20	34	
	Middle	21	34	124.9	21	33	123.8	21	34	123.7
	End	21	35		21	32		20	34	
1000-1050	Start	21	31		21	32		20	34	
	Middle	21	32	124.9	20	32	123.3	21	35	123.2
	End	21	32		20	32		20	34	
Composite Av.		22	37	124.7	21	35	123.7	21	33	123.8

No. of Extension		Diaphragm 4 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 4 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 4 Bursting Strength, p.s.i.g.	Diaphragm 5 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 5 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 5 Bursting Strength, p.s.i.g.	Composite Average Diaphragm Pressure, p.s.i.g. 3/8 inch	Composite Average Diaphragm Pressure, p.s.i.g. 1.8 cm.	Composite Average Bursting Strength, p.s.i.g.
0-50	Start	24	60		20	41				
	Middle	25	53	125.1	22	44	124.8	22	48	124.0
	End	24	59		22	43				
250-300	Start	24	49		21	40				
	Middle	26	48	124.5	22	41	123.4	22	40	124.2
	End	25	48		22	40				
500-550	Start	24	44		21	36				
	Middle	25	44	125.5	22	37	126.0	22	37	125.0
	End	24	44		21	36				
750-800	Start	23	40		21	35				
	Middle	23	40	125.1	21	36	124.4	21	35	124.4
	End	24	41		21	35				
1000-1050	Start	23	39		21	33				
	Middle	23	39	124.5	21	34	123.5	21	34	123.9
	End	22	38		20	33				
Composite Av.		24	46	124.9	21	36	124.4	22	39	124.3

Note: This style is identified as 305-A.

TABLE IV

"LIFE" TESTS USING NEW STYLE DIAPHRAGMS MOLDED FROM SIRVENE 409641

No. of Extension		Diaphragm 1			Diaphragm 2			Diaphragm 3			Diaphragm 4			Diaphragm 5			Composite Average		
		Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.
		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.	
0-50	Start	24	52		25	68		26	57		24	58		25	54				
	Middle	25	50	125.6	27	68	122.6	26	58	125.0	26	62	123.7	26	56	124.8	25	59	124.3
	End	24	52		26	68		27	57		25	61		26	60				
250-300	Start	25	58		25	54		26	55		25	60		26	47				
	Middle	26	56	125.3	25	54	124.9	26	53	126.8	27	62	126.7	25	48	126.8	26	54	126.1
	End	25	55		26	52		26	53		27	62		26	50				
500-550	Start	26	48		25	44		26	47		26	55		26	44				
	Middle	26	48	126.8	25	43	125.9	27	47	126.6	27	52	126.0	25	45	127.0	25	47	126.5
	End	26	48		25	42		26	47		26	51		26	46				
750-800	Start	25	45		24	43		25	45		25	47		25	41				
	Middle	26	46	125.0	25	43	122.9	25	45	126.3	26	45	124.9	25	42	126.3	25	44	125.1
	End	26	46		25	43		25	45		26	46		25	40				
1000-1050	Start	24	43		25	41		26	42		25	45		25	41				
	Middle	24	43	126.0	26	43	122.7	26	43	127.1	26	45	122.4	25	40	123.7	25	43	124.4
	End	24	43		24	42		25	43		25	45		25	41				
Composite Av.		25	49	125.7	25	50	123.8	26	49	126.4	26	53	124.7	25	46	125.7	25	49	125.3

Note: This diaphragm style is denoted as 305-B.

TABLE V

"LIFE" TESTS USING NEW STYLE DIAPHRAGMS AS SUPPLIED CURRENTLY FOR COMMERCIAL SERVICE

No. of Extension		Diaphragm 1 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 1 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 1 Bursting Strength, p.s.i.g.	Diaphragm 2 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 2 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 2 Bursting Strength, p.s.i.g.	Diaphragm 3 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 3 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 3 Bursting Strength, p.s.i.g.
0-50	Start	32	68		28	65		31	72	
	Middle	33	32	126.2	29	63	124.6	32	75	128.2
	End	33	75		30	61		31	72	
250-300	Start	33	69		28	50		32	60	
	Middle	33	69	127.7	29	51	126.4	32	58	127.4
	End	32	62		29	50		32	59	
500-550	Start	30	50		29	49		30	55	
	Middle	33	60	127.6	30	50	125.5	30	56	126.0
	End	32	60		29	48		31	55	
750-800	Start	31	55		29	49		30	55	
	Middle	32	53	125.7	29	49	124.0	31	54	127.0
	End	31	53		28	48		30	53	
1000-1050	Start	31	49		28	45		29	50	
	Middle	31	51	124.0	28	45	125.5	30	51	125.7
	End	31	49		27	44		29	49	
Composite Av.		32	61	126.2	29	51	125.2	31	58	126.9

No. of Extension		Diaphragm 4 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 4 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 4 Bursting Strength, p.s.i.g.	Diaphragm 5 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 5 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 5 Bursting Strength, p.s.i.g.	Composite Average Diaphragm Pressure, p.s.i.g. 3/8 inch	Composite Average Diaphragm Pressure, p.s.i.g. 1.8 cm.	Composite Average Bursting Strength, p.s.i.g.
0-50	Start	23	43		30	78				
	Middle	24	43	122.3	31	77	123.7	29	66	125.0
	End	23	42		31	73				
250-300	Start	23	41		30	68				
	Middle	23	41	122.3	29	67	125.0	29	57	125.8
	End	23	42		30	71				
500-550	Start	23	39		30	62				
	Middle	23	38	122.6	30	60	124.9	29	53	125.3
	End	22	38		31	61				
750-800	Start	22	36		30	60				
	Middle	23	36	123.3	31	61	125.9	28	51	125.2
	End	22	35		30	59				
1000-1050	Start	22	34		30	54				
	Middle	22	34	124.5	30	57	125.7	28	47	125.1
	End	22	34		30	57				
Composite Av.		23	38	123.0	30	64	125.0	29	55	125.3

Note: The diaphragm style is identified as 305-B.

TABLE VI

"LIFE" TESTS USING OLD STYLE DIAPHRAGMS MOLDED FROM NATURAL RUBBER

No. of Extension		Diaphragm 1 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 1 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 1 Bursting Strength, p.s.i.g.	Diaphragm 2 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 2 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 2 Bursting Strength, p.s.i.g.	Diaphragm 3 Diaphragm Pressure, p.s.i.g. 3/8 inch	Diaphragm 3 Diaphragm Pressure, p.s.i.g. 1.8 cm.	Diaphragm 3 Bursting Strength, p.s.i.g.	Composite Average Diaphragm Pressure, p.s.i.g. 3/8 inch	Composite Average Diaphragm Pressure, p.s.i.g. 1.8 cm.	Composite Average Bursting Strength, p.s.i.g.
0-50	Start	34	65		34	69		31	50				
	Middle	35	65	126.1	36	72	125.7	32	52	121.5	34	66	124.4
	End	34	64		37	75		33	54				
250-300	Start	33	60		35	62		31	54				
	Middle	34	59	127.9	35	62	127.8	31	54	125.9	33	58	127.2
	End	33	59		35	60		31	53				
500-550	Start	32	57		35	59		31	53				
	Middle	33	58	126.2	35	58	126.1	31	51	127.6	33	56	126.6
	End	32	57		34	57		30	51				
750-800	Start	32	55		33	57		29	49				
	Middle	31	55	125.6	34	58	125.3	30	49	125.2	32	54	125.4
	End	32	54		34	57		30	49				
1000-1050	Start	32	53		33	55		29	49				
	Middle	31	53	126.5	32	56	124.4	29	48	122.7	31	52	124.5
	End	31	53		32	55		29	48				
Composite Av.		33	58	126.5	34	61	125.9	30	53	124.6	33	57	125.6

Note: This diaphragm style is identified as 305-A.

TABLE VII

SUMMARY OF LIFE TEST RESULTS

No. of Extensions	Type 305-A Sirvene 409641			Type 305-B Sirvene 409641			Type 305-3 Current Composition			Type 305-A Natural Rubber Composition		
	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.	Diaphragm Pressure, p.s.i.g.		Bursting Strength, p.s.i.g.
	3/8 inch	1.8 cm.		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.		3/8 inch	1.8 cm.	
0-50	22	48	124.0	25	59	124.3	29	66	125.0	34	66	124.4
250-300	22	40	124.2	26	54	126.1	29	57	125.8	33	58	127.2
500-550	22	37	125.0	26	47	126.5	29	53	125.3	33	56	126.6
750-800	21	35	124.4	25	44	125.1	23	51	125.2	32	54	125.4
1000-1050	21	34	123.9	25	43	124.4	28	47	125.1	31	52	124.5
Composite Av.	22	39	124.3	25	49	125.3	29	55	125.3	33	57	125.6
% Diff.[a]	-24.1	-29.1	-0.8	-13.8	-10.9	0.0	—	--	—	+13.8	+3.6	+0.2

[a] Based arbitrarily on current commercial diaphragms.

5. In terms of over-all averages, the differences in bursting strength between diaphragm types were relatively small--implying that the differences in diaphragm pressure encountered herein were not sufficient to cause marked differences in test results.

6. In terms of Rule 41

a. The Type 305A, Sirvene 409641, diaphragms were below specifications on the average.

b. The natural rubber Type 305A diaphragms were above specifications on the average.

DIAPHRAGM CONTRIBUTION AS DETERMINED FROM PRESSURE VS. DISTENTION CHARACTERISTICS

As mentioned previously, a bursting strength reading equals the sum of the diaphragm contribution plus the inherent burst strength in the test area of the specimen. To a first approximation, at least, the diaphragm contribution may be assumed to equal the pressure required to distend the diaphragm (with no test specimen in place) to an extension equal to that obtained in the normal test. While this neglects the interaction between sample and diaphragm during the normal test, complete simulation of the sample-diaphragm interaction considerably complicates the experimental work. For this reason, it was felt desirable to experimentally explore the simpler approach in this phase of the program.

In brief, this approach required that pressure vs. distention curves be obtained for (a) the diaphragm alone and (b) diaphragm and test specimen.

From (b) the distention at failure may be measured. The diaphragm pressure at the failure distention may then be read from the curve(s) for the diaphragm alone.

Using the apparatus described earlier, exploratory tests were made with both 42-lb. liner and aluminum foil as the test material. Three types of diaphragms were selected for the initial trials as follows:

(a) Dental dam--with kraft liner only

(b) Type 305A, Sirvene 409641

(c) Type 305B, Current commercial composition.

The results obtained are summarized in Table VIII. Referring to the table, it may be observed that -

1. For the kraft liner, the distention at failure was constant at about 0.14 inches both in the initial tests and in those carried out after 200 tests. Since the distention at failure is governed by the stretch of the sheet, it may be anticipated that most conventional grades of linerboard will give similar results.

2. As a result of the low distention at failure, using kraft liner, the apparent diaphragm contribution for the regular diaphragms was near 8 p.s.i.g.--or from 5 to 7% of the test average.

3. The diaphragm contributions for the two types of regular diaphragms were nearly equal. This would indicate that the bursting strength results using the two types of diaphragms should also be approximately equal for samples failing at about the same extension--in qualitative agreement, at least, with the "life" data previously discussed.

TABLE VIII

EXPLORATORY TRIAL OF PRESSURE DISTENTION TECHNIQUE FOR EVALUATING

DIAPHRAGM CONTRIBUTION

Type of Diaphragm	Diaphragm Pressure, p.s.i.g. 3/8 in.	Diaphragm Pressure, p.s.i.g. 1.8 cm.	Distention at Failure, inches	Apparent Diaphragm Contribution at Failure, p.s.i.g.	Bursting Strength,[a] p.s.i.g.	Per Cent Diaphragm Contribution[b]
42-lb. Kraft Liner—Initial Tests						
Dental dam	1.0	1.5	0.14	< 1.0	125.1	<0.8
305A, Sirvene 409641	24	43	0.14	7	128.1	5.5
Current commercial (305B)	28	62	0.13	8	128.2	6.2
42-lb. Kraft Liner--After 200 Tests						
305A, Sirvene 409641	26	43	0.14	9	126.1	7.1
Current commercial (305B)	30	71	0.14	8	130.9	6.1
0.003 inch Annealed Aluminum Foil						
305A, Sirvene 409641	26	69	0.33	24	117.1	20.5
Current commercial (305B)	31	74	0.31	26	118.1	22.0

[a] n = 20

[b] Based on test averages as reference.

4. With the "annealed" foil, distention at failure was considerably greater. As a consequence, the diaphragm contribution was substantially greater--both in an absolute or percentage basis.

5. For the kraft liner tests, a greater difference in test results between the dental dam and regular diaphragms would have been expected in view of the experimental values for diaphragm contribution.

Keeping in mind the exploratory nature of the above results, the relatively small values recorded for the apparent diaphragm contribution and the low distention at failure for the kraft linerboard sample may explain why relatively great tolerances in diaphragm pressure at higher extensions for the type of board--23 to 30 p.s.i.g. at 3/8 inch extension--may be acceptable. For example, in Fig. 6 straight lines have been drawn from the origin through the tolerance limits at 3/8 inches. Reading in at an extension of 0.14 inches, the curves suggest that the difference in apparent diaphragm contribution would amount to about 2.7 p.s.i.g. at a level of about 10 p.s.i.g. These values appear to be in qualitative agreement, at least, with the results obtained from the diaphragm distention pressure curves.

It is believed, however, that the experimental technique used herein should permit direct re-evaluation of diaphragm effects as affected by test material, type of diaphragm, and history (number of tests). Further work will be directed along these lines.

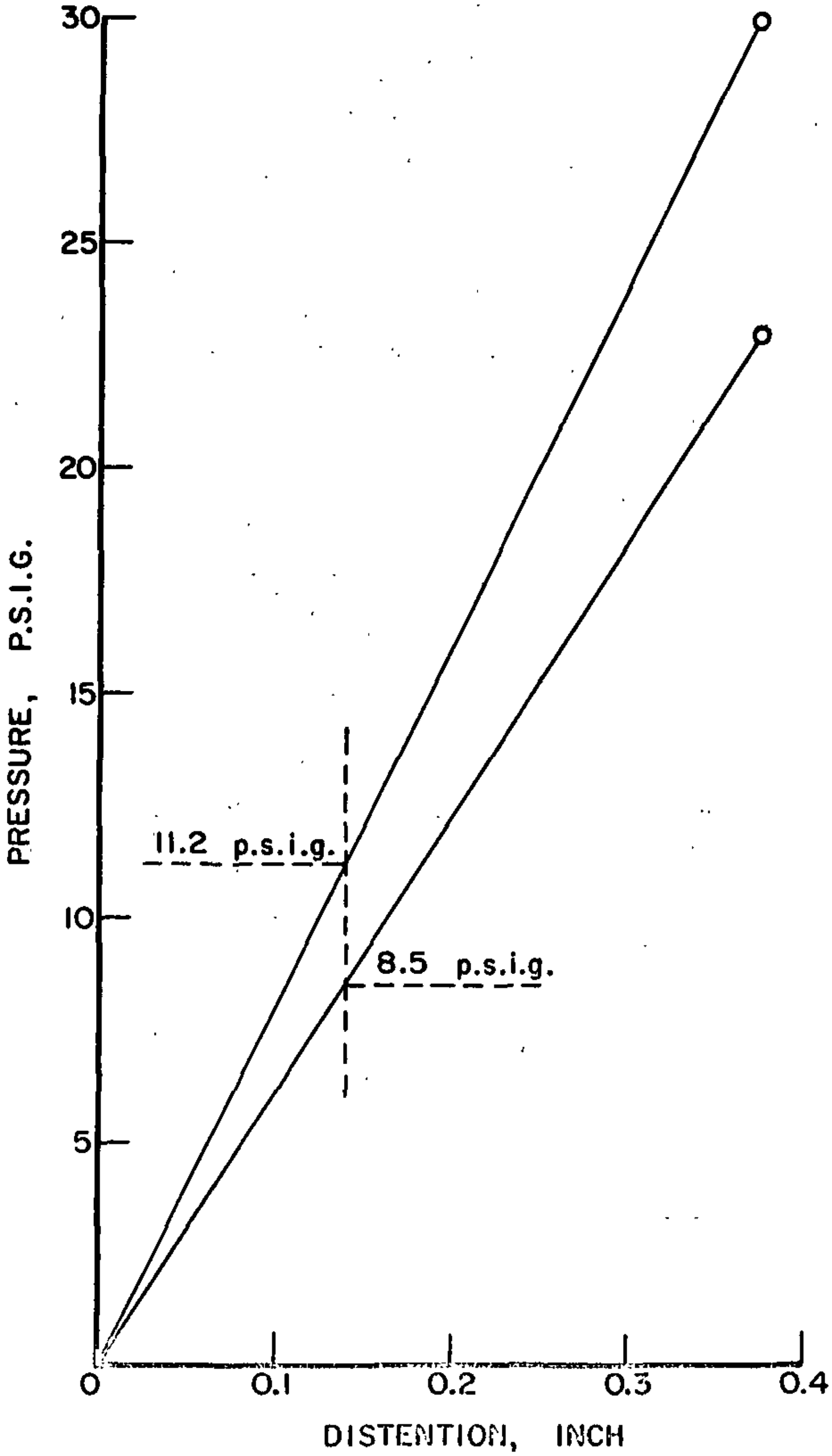


Figure 6. Schematic Extrapolation of Diaphragm Pressure Specifications at 3/8 Inch to a Failure Distention of 0.14 Inches

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